

PEARSON

Drawing Response Interaction USABILITY STUDY for PARCC

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July 28- July 30, 2015

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EXECUTIVE SUMMARY

A usability study was conducted by the Research and Innovation Network and Assessment Solutions Design to assess the usability of a drawing response interaction type. The Partnership for Assessment of Readiness for College and Careers (PARCC) commissioned a multi-part study to determine the viability of using the drawing response interaction on the PARCC Mathematics Assessment. In the first part of the study, participants in grades 3, 9, 10, and 11 (during the 2014-2015 school year) participated. Participants completed a series of math questions on the computer or iPad that included the drawing response interaction, while observation and video recording took place.

The goal of this study was to test the usability of the drawing response interaction feature and determine if and how it assists participants in problem solving. The team also wanted to gather feedback from the participants on how they would change the drawing response interaction to best help them solve problems.

Positive findings from the study include the following:

- Participants were generally comfortable using the drawing response interaction for basic tasks
- Participants generally liked the drawing response interaction and thought they would use it when solving problems

Issues revealed during this study include the following:

- Participants were generally confused by the eraser and had difficulty erasing their work
- Participants were very challenged by the math content and, at times, were unable to give feedback on the drawing response interaction because of this
- Participants were frustrated by the drawing response interaction's lack of precision, in both iPad and desktop/mouse solutions, particularly 3rd graders, whose fine motor skills are not well-developed
- Participants were concerned with their drawing ability and how that might impact their test scores

Recommendations for future studies:

- Adjust the eraser tool
- Include a library of shapes and other tools to help participants create more accurate work in the drawing response interaction
- Adjust the rigor of math questions included

- Include clear instructions for how and where participants should show their work and answers

INTRODUCTION

The PARCC Tests assess participants' current performance on rigorous state standards for math and Language Arts; the tests are designed to not only assess for correctness, but to also look for evidence that a participant understands and can apply their knowledge. The goal of the study was to gather feedback on a drawing response interaction, which may be integrated into the PARCC assessment. Pearson is working with PARCC to deliver a flexible drawing response interaction feature to enable participants to record and submit their handwritten work and answers for math problems.

Purpose

Pearson's Assessment Solutions Design team wanted to gather information on the usability of the drawing response interaction on a computer and iPad and its usefulness to participants in problem solving.

The team also recorded observations about physical interaction with the iPad and desktop computer, with a focus on the usability of the drawing response interaction.

Test Objectives

- Can participants use the drawing response interaction to help them solve math problems?
- What features do participants want to add to the drawing response interaction?

General Observation Objectives

- Will participants be able to successfully complete the test questions?
 - Without moderator prompts?
 - With using the drawing response interaction?
- Will participants encounter any difficulties with the drawing response interaction features?
- Will participants encounter any general technological difficulties with the computer or iPad?

User Profile

There were twelve total participants, including six third graders, four ninth graders, one tenth grader, and one eleventh grader. Note that grade levels were taken as of the 2014-2015 school year. All participants self-reported as comfortable (scores of 4 or 5 on a 1 to 5 scale) with math on the initial survey they filled out.

Participant	Grade	Gender	Use of computer for math?	Test Tool (Computer or iPad)	Math Comfort Level (1=not confident at all, 5=extremely confident)	Math Courses Taken (for HS participants)
P1	9	Female	No—only paper/pencil	Computer	4	Algebra I, Geometry
P2	3	Male	No—but has used art apps	Computer	4	
P3	3	Male	No	Computer	Comfortable, did not ask rating	
P4	3	Female	Yes—uses an app for basic math at school	Computer	4	
P5	10	Male	Yes—in his dual enrollment math course	Computer	4	Algebra I, Geometry, Algebra II, Trigonometry
P6	9	Female	Yes—uses WebWorks and has taken state tests online	Computer	5	Algebra 1, Geometry
P7	3	Male	No	iPad	4	
P8	3	Female		iPad	5	
P9	9	Male	Yes—has used Galileo	iPad	4	Algebra I, Geometry
P10	11	Female		iPad	4	Algebra I, Geometry, Algebra II, Pre-Calculus
P11	3	Male		iPad	4	
P12	9	Female	Yes—uses	iPad	5	Algebra I, Geometry,

			online textbook			Algebra II
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METHODS

The usability test was completed within 60 minutes. The test was designed to analyze and measure the effectiveness of the drawing response interaction in helping participants solve math problems and gather feedback from the participants on what functionality they would add to the drawing response interaction. Each participant session was organized in the same way to facilitate consistency. Video and audio recordings and moderator/note-taker observations were used to collect data.

Test Details

Recruitment (pre-test)

Participants were recruited through an initial recruitment email with a short explanation of the study, along with the dates and incentive information. Inside the email was a link to a survey that parents could fill out to determine math comfort. The survey included the following questions: 1) Rate your child's confidence level (1-5), with 1 being Not at all Confident and 5 being Extremely Confident, with activities related to mathematics (math games, math assignments, math tests, etc.), 2) (for high school participants only) From the list, please select the math courses that your child has completed: Algebra I, Geometry, Algebra II, Trigonometry, Calculus, Other.

Introduction/Demographic Interview (2 - 5 minutes)

The moderator explained that the purpose of the test was to review online tools embedded in a high-stakes assessment. Participants answered questions to get a sense of their past use of technology products in their math courses. These questions allowed us to gain an understanding of the participant's previous use of technology with math while giving the participant a chance to get comfortable. Last, the moderator emphasized that we are not testing the participant's ability to solve the math problems but rather their perceptions of the online tools.

Prototype Testing / Follow Up Interview (25 - 45 minutes)

The moderator explained that the participant should imagine that he/she is about to take a test online and asked them to pretend this was a high stakes test similar to one they would take at the end of the year. The moderator instructed the participant to "think aloud" as he/she completed the tasks to let us know what he/she was thinking. The test was delivered via a desktop computer for three of the third graders and three

of the high schoolers and via an iPad for the remaining three third graders and three high schoolers.

Farewell (1 - 2 minutes)

When the task list was finished, participants were prompted to provide any other relevant feedback. Participants received an honorarium at the end of the session.

After test data had been collected, notes and video data were reviewed and coded to determine themes.

Test Environment

Usability testing was conducted in the Idea Innovation Center in the Pearson Chandler office. Participants sat at a table with a moderator. In person observers/note-takers sat behind the one-way mirror, and one remote observer/note-taker joined by phone and WebEx. For each session, the audio and screen movements were recorded using Ovo.

Test Moderator/Observer Role

Before the session, two of the observers/note-takers retrieved participants from the Chandler office lobby. They answered any questions the participant/guardian or parent had and then walked the participant to the Idea Innovation Center.

The moderator met the participant in the Idea Innovation Center and introduced and administered the usability test, referencing a test script as needed. The moderator introduced the participants to the assessment and informed them of the new tool. The moderator explained that we were more interested in the participant's perception of the tools than of their ability to answer the math questions correctly. The moderator explained the "think aloud" procedure for the session and answered any preliminary questions. The moderator administered the test and asked the participants to rate the tasks completed during the session on a scale of 1 to 7, 1 being very difficult and 7 being very easy. At the end of the session, the moderator presented the participant with a \$50 Visa gift card. After the session, one of the observers/note-takers walked the participant back to the Chandler office lobby.

During each interview, the observers operated the lab cameras and recording software. The observers took notes on the feedback from the sessions. After each interview, the moderator organized and posted video footage for review.

Test Format/Prototype Overview

The test was divided into three phases.

1. In the first phase, all participants interacted with three tasks which required them to draw basic shapes (a line, a circle, and a picture to illustrate one half). High school participants interacted with two additional tasks--graphing a line and drawing a geometric figure. These tasks were written specifically for this usability study and were designed to test whether or not participants could interact with the drawing response interaction on a basic level.
2. In the second phase, participants interacted with a series of tasks that required them to solve (or attempt to solve) a question using the drawing response interaction. These questions were drawn from: a) PARCC assessment questions which participants including a drawing on the paper assessment and were modified for security reasons for this usability test, b) PARCC practice and sample test questions. For the third grade participants, tasks were drawn from grade 3 items, and for the high school participants, tasks were drawn from Algebra I and Geometry items.
3. In the third phase, participants interacted with a series of tasks that were identified as candidates for inclusion of the drawing response interaction. For these tasks, participants were not asked to solve, but were asked if they would use the drawing response interaction, and if so, how they would use it and what features they would want added.

Evaluation Measures

For each usability study objective, the following measures will be used:

- Observation of users' interactions with the drawing response interaction
- Verbal feedback during follow-up questions
- Participant ratings (on a scale of 1 to 7, 1 being very difficult, 7 being very easy) for each task

RESULTS

Twelve participants participated in PARCC's drawing response interaction usability study. Video and audio recordings are available for all twelve interviews (see Appendix 2). One participant became frustrated during the interview and decided to stop early; we included the responses and feedback she was able to provide.

Results are broken down by task and grade level (third or high school).

Previous Technology Usage with Mathematics

Prior to beginning the usability test, participants were probed regarding their use of technology with math.

- **3 of 12 participants reported using some sort of drawing/art app for fun**
- **5 of 12 participants reported using some sort of technology in their math courses**
 - P4 uses an app for basic math (adding, subtracting, multiplying, dividing) at school
 - P5 uses the computer for his dual enrollment math course
 - P6 uses WebWork for her math homework and has taken state math tests on the computer, using tools such as rulers, calculators, and highlighters
 - P9 uses Galileo in his math course
 - P12 uses an online textbook for his math course

Task-Level Analysis for Third Graders & High Schoolers

General Perceptions of the Drawing Response Interaction

In general, participants liked the drawing response interaction and could use it for simple tasks

- 12 of 12 participants were able to draw a line using the drawing response interaction
- 12 of 12 participants were able to draw a circle using the drawing response interaction
- P5: "I really like the drawing response interaction--it's simple. Being able to draw it out helps a lot with problem solving."
- P5: "Especially for me, math is easier using pictures so you can see what you are doing."
- P9: "A drawing box is good for any [problem] so you can write down little notes."

In general, participants recognized the drawing response interaction features

- 9 of 12 participants verbally pointed out the color icons
- 5 of 12 participants verbally pointed out the eraser icon

In general, participants wanted the drawing response interaction to be more accurate

- P9: "I want [drawing response interaction] to be more precise."
- P12: "Drawing it out is a nice concept, but it's a lot easier if the numbers are exact--lines are exactly the same, etc."
- P11: "I would like to write [my response] smaller and neater."
- P12: "Honestly, it would be hard to draw a perfect circle."
- P6: "It's important for me to be able to draw a perfect circle."
- P1: "I don't want to be judged off of my artistic skills."

3 of 12 participants were concerned about/were hesitant to use the drawing response interaction

- P2: "I wouldn't use pictures on a test unless I had to. They take up too much time, and I'm bad at drawing."
- P11: "I think if you had a time limit, [typing] it would be a lot faster."
- P11: "I want to do it on a piece of paper. I am frustrated by having to use the drawing response interaction."
- P3: "If I couldn't figure out the problem, I might draw, but otherwise, I would just use numbers."

11 of 12 participants struggled with the math content on one or more problems. This impacted their ability to assess the drawing response interaction

- P6: "The (drawing) tools aren't difficult, but the problem itself is confusing."
- 1 of 12 participants (P4) was able to consistently and efficiently use the drawing response interaction to draw visual representations. She mentioned that she draws pictures in math at school.

8 of 12 participants were unable to figure out the eraser tool

- 5 of 6 third grade participants were unable to figure out the "x" eraser tool
- 3 of 6 high school participants were unable to figure out the "x" eraser tool
- Participants expected to be able to drag the eraser tool

Tasks 1 & 2: Using the drawing response interaction for Basic Tasks

Participants were instructed to: 1) Use the pencil to draw a line in the box; 2) Use the pencil to draw a circle in the box.

3rd Graders

6 of 6 participants were able to use the drawing response interaction to draw a line and circle

Rating

- 5 of 7 participants rated using the drawing response interaction for this task a 6 or 7 (on a scale of 1 to 7, 1 being very difficult, 7 being very easy)
- Average rating: 6.5

Recommended features

- Draggable Eraser Tool
 - 3 of 6 participants want a draggable eraser tool
 - "I would like [the eraser] to work like this (makes swiping motion)--just swiping." (P11)
- Library of shapes to drag into the drawing response interaction (P2)
- Tools to use in the drawing response interaction (ex: straightedge, compass) (P4)

High Schoolers

6 of 6 participants were able to use the drawing response interaction to draw a line and circle

Rating

- 6 of 6 participants rated using the drawing response interaction for this task a 6 or 7
- Average rating: 6.8

Recommended features

- Library of shapes to drag into the drawing response interaction (P1, P10)

Task 3: Using the Drawing Response Interaction for Basic Tasks

Participants were instructed to: Draw a picture to show 1/2.

3rd Graders

6 of 6 participants were able to use the drawing response interaction to attempt this task

- Not all participants drew a correct answer

Rating

- 3 of 5 participants rated using the drawing response interaction for this task a 6 or 7
 - Note:* 1 participant did not rate this question
- Average rating: 5.6
- P7 rated a 2 because he didn't know how to erase

Recommended features

- Library of shapes to drag into the drawing response interaction (P2)
 - P2: "For littler kids, it would be better if there were shapes you could add."
- Autocorrect shapes (P11)

High Schoolers

6 of 6 participants were able to use the drawing response interaction to attempt this task

- Not all participants drew a correct answer

Rating

- 6 of 6 participants rated using the drawing response interaction for this task a 6 or 7
- Average rating: 6.8

Recommended features

- Tool to automatically shade a shape (P9, P10, P12)
- Tool to help draw a line in the middle of a shape (P12)

Third Grade Tasks:

Task 4

Participants were instructed to solve: There are 25 people going to a picnic in the park. There are 5 tables. One of the tables will be used for food. The other tables each can seat 6 people.

3 of 6 participants did not understand the question, which may have impacted their ability to give feedback on the drawing response interaction (P2, P3, P7)

Participants used the drawing response interaction/textbox in different ways

- 3 of 6 participants only used the drawing response interaction (P7, P4, P3)
- 2 of 6 participants used the drawing response interaction and textbox (P11, P8)
- 1 of 6 participants only used the textbox (P1)

One participant ran out of room in the drawing response interaction

- P7: "Going outside the lines of the [drawing response interaction] was hard."

Rating

- Solving: 3 of 6 participants rated solving this task a 6 or 7; 3 of 6 participants rated solving this task a 1
 - Average rating: 3.7
- Drawing response interaction: 4 of 6 participants rated using the drawing response interaction for this task a 6 or 7
 - Average rating: 5.5

Recommended Features

- Library of shapes to drag into the drawing response interaction (P2, P7, P11, P8)
- Ability to draw straight lines (P4)
- Ability to stretch/shrink shapes (P2)
- Ability to copy/paste shapes in the drawing response interaction (P2)

Task 5

Participants were instructed to solve: Sophie is comparing the fractions $\frac{2}{3}$ and $\frac{2}{4}$. She says that $\frac{2}{4}$ is bigger. Is she correct? Show your work or explain your answer using words, numbers, and pictures.

2 of 6 participants ran out of room in the drawing response interaction (S8, S11)

- P11: "Is there a way to make [my response] smaller?"
- P8: "Oh, I think I need a bigger box!"

5 of 6 participants used the drawing response interaction

- 1 of 6 participants used only the textbox (P11)

Rating

- Solving: 3 participants rated solving this task as a 6 or 7
 - Average rating: 5.2
- Drawing response interaction: 2 of 6 participants rated using the drawing response interaction as a 6 or 7
 - Average rating: 5
 - participants rated lower than 6 due to issues with making their shapes and lines precise

Recommended Features

- Tool to automatically shade a shape (P4)
 - "Shading shapes is difficult." (P4)

Task 6

Participants were instructed to solve: Robert is putting toy cars into 8 groups. One jar has 25 toy cars and another jar has 23 toy cars. He wants the same number in each group. How many toy cars will be in each group? Show your work or explain your answer using words, numbers, and pictures.

2 of 6 participants did not understand the question, which may have impacted their ability to give feedback on the drawing response interaction (P2, P7)

- P2: "I'm confused because I know how many groups there are, but I don't know what the groups are--are they the cars?"
- P7: "I don't get this one."

2 of 6 participants did not use the drawing response interaction for this problem

- P3: "If I couldn't figure out a problem, I might draw, but otherwise, I would use numbers."
- P11: "It would take awhile for me to draw the cars. If I just write the answer, it will be a lot faster."

One participant ran out of room in the drawing response interaction

- P4: "I would write my answer in the [drawing response interaction], but my box is full."

Rating

- Solving: 3 of 6 participants rated solving this problem as a 6 or 7
 - Average: 5
- Drawing response interaction: 2 of 6 participants rated using the drawing response interaction as a 6 or 7
 - Average: 5
 - P8 rated a 3 because "you couldn't really draw the dots in [the drawing response interaction]."

Recommended Features

- Library of shapes to drag into drawing response interaction (P2)
- Ability to add labels to the drawing response interaction (P2)

Task 7

Participants were instructed to solve: A) Adam needs to put 19 pictures from Classroom A and 23 pictures from Classroom B on a bulletin board. He wants to display the pictures in an array. Draw an array to represent the pictures on the bulletin board. There is space for up to 10 pictures across and down on the bulletin board. B) Find the area of the array.

4 of 6 participants drew something for Part A but were incorrect (S2, S7, S11, S3)

participants had trouble drawing dots to represent pictures in the array

- P11: "I wrote [the dots] kind of big, so I couldn't fit them."

3 of 6 participants had to start over and erase due to lack of space or difficulties with drawing

- P11: "Cause I accidentally did 7 (dots) instead of 10 and I wrote them kinda big so I couldn't fit them."

Rating

- Solving: 1 participant rated solving this problem a 6 or 7; 2 participants rated solving

this problem a 1

- *Note:* One participant did not rate this question
- Drawing response interaction: 0 participants rated the drawing response interaction a 6 or 7; 3 participants rated the drawing response interaction a 3
 - *Note:* One participant did not rate this question
 - P3: Rated a 3 “because I had to erase and start over.”
 - P7: Rated a 1 “because I didn’t have enough lines and it didn’t make sense--it was hard to draw lines.”

Recommended Features

- Library of shapes to drag into drawing response interaction (P3)
- Ability to draw straight lines (P4)

Task 8

Participants were instructed to solve: Tori and Leo set up their clubhouse with four tables. These rectangles represent the tabletops. A) Identify **two** tabletops with the same area, in square feet, and explain how you know the areas are equal. Enter your answers and your explanation in the space provided.

3 of 6 participants sketched a picture/diagram (P2, P4, P7)

2 of 6 participants were unable to answer the question

- 1 of 6 participants began crying and stopped the test (P8)
- 1 of 6 participants said “I’m not really sure how to do this” and was not able to sketch or type an answer (S11)

Rating

- *Note:* Only 2 participants provided ratings for this task.

Recommended Features

- Library of shapes to drag into drawing response interaction (P2, P3, P7)
- Ability to draw straight lines (P2)
- Ability to stretch/shrink shapes (P2)

Task 9

Participants were instructed to solve: Martin cut a pan of cornbread into equal pieces as shown in the model. A) Martin gave $\frac{1}{3}$ of the corn bread to his neighbor. Explain how you can use the model to show $\frac{1}{3}$. Then write a fraction that is equivalent to $\frac{1}{3}$. B) Martin gave 6/12 of the corn bread to his teacher. Write a comparison using $<$, $>$, or $=$ to compare the fractions $\frac{1}{3}$ and 6/12. Explain how the model can be used to compare these fractions. Enter your comparison and your explanation in the space provided.

5 of 5 participants wanted the drawing response interaction to help them solve this problem

- Note: For the duration of the tasks, there are only 5 participant participants.

3 of 5 participants wanted to use the drawing response interaction to shade part of the given diagram (P7, P9, P11)

3 of 5 participants wanted to draw their own representation of the pan (P2, P3, P4)

Recommended Features

- Tool to automatically shade a shape (P2, P3, P7, P11)

Task 10

Participants were instructed to solve: Nolan has 16 pennies in one jar and 94 pennies in another jar. He uses some of the pennies to buy a pencil that costs 25 cents. What is the total number of pennies Nolan has left after he buys the pencil? Show your work. Enter your answer and your work in the space provided.

4 of 5 participants wanted the drawing response interaction to help them solve this problem (P3, P4, P7, P11)

- 1 of 5 participants preferred to use numbers, not pictures, to solve the problem (P2)
 - “It would be easier to solve the problem using just numbers and not the drawing response interaction” (P2)

Recommended Features

- Pictures of objects (like pennies) to drag into the drawing response interaction (P11)

Task 11

Participants were instructed to solve: A) Shaun plotted a point on the number line by drawing 5 equally spaced marks between 0 and 1 and placing a point on the third mark. He claims that the point represents the fraction $\frac{3}{5}$ because each mark represents $\frac{1}{5}$, so the third mark represents $\frac{3}{5}$. Explain why Shaun's reasoning is incorrect. Explain how you can use the number line to determine the fraction that Shaun's point represents. Determine the fraction that Shaun's point represents. B) Shaun wants to write a fraction that is equivalent to the fraction $\frac{3}{5}$. Describe how Shaun can find a fraction that is equivalent to $\frac{3}{5}$.

3 of 5 participants wanted the drawing response interaction to help them solve this problem (P2, P4, P7)

- 1 of 5 participants indicated he would not use the drawing response interaction (P3)
- 1 of 5 participants was not able to attempt the problem (P11)

Participants wanted to use the drawing response interaction to represent the number line

- Of the 3 participants who indicated they wanted to use the drawing response interaction:
 - 1 of 3 participants wanted to draw on the given number line (P7)
 - 2 of 3 participants wanted to recreate the number line (P2, P4)

Recommended Features

- Tool to automatically add a number line (P2)
- Ability to draw straight lines (P4)
- Ability to add labels (P4)

Task 12

Participants were instructed to solve: Ms. Morales has a bag of beads. She gives Elena 5 beads. She gives Damian 8 beads more than Elena. She gives Trish 4 times as many beads as Damian. Ms. Morales then has 10 beads left in the bag. How many beads did Damian and Trish each receive?

3 of 5 participants did not want to use the drawing response interaction to help them solve the problem (P2, P3, P7)

- P2: "You could solve with just multiplication or addition."
- P7: "I would just do it in my head and write the answer down."

Recommended Features

- Library of shapes to drag into drawing response interaction (P4)
- Ability to add labels (P4)

High School Tasks:

Task 4

Participants were instructed to solve: Draw a graph to show $y=3x-1$.

4 of 6 participants were confused by the task and unable to complete the problem correctly

- 2 of 6 participants correctly completed the task (P6, P12)

6 of 6 participants wanted a coordinate plane they could drag into the drawing response interaction

- 5 of 6 participants independently stated they wanted a coordinate plane to drag into the drawing response interaction
- 1 of 6 participants, when prompted, stated he wanted a coordinate plane to drag into the drawing response interaction

Rating

- 5 of 6 participants rated using the drawing response interaction a 6 or 7
- 1 of 6 participants rated using the drawing response interaction a 1 because he did not understand how to solve the problem (P9)
- Average: 5.3

Recommended Features

- Graphs/grids to drag into the drawing response interaction (P1, P5, P6, P9, P12)
- Ability to draw straight lines (P10, P12)
- Ability to add “dots” to the drawing response interaction (P12)

Task 5

Participants were instructed to solve: Draw an isosceles triangle and the altitude. Mark equal sides and the right angle.

6 of 6 participants attempted the task using the drawing response interaction

- 2 of 6 participants drew right isosceles triangles
- 2 of 6 participants used different colors to complete the task

Rating

- Solving: 5 of 6 participants rated solving the problem a 6 or 7
 - Average: 5.8
- Drawing response interaction: 4 of 6 participants rated using the drawing response interaction a 6 or 7

- Average: 6.2

Recommended Features

- Tools to use in drawing response interaction (ex: straightedge, compass) (P1, P5)
- Ability to draw straight lines (P5, P10, P12)
- Library of shapes to drag into drawing response interaction (P12)

Task 6

Participants were instructed to solve: In a system of two linear equations, the lines represented by each equation have the same slope. A) What could be the total number of solutions to the system of equations? B) Explain why you chose your answer in Part A.

1 of 6 participants completed the problem completely and correctly (P10)

5 of 6 participants used the drawing response interaction and the textbox to answer the question (P1, P6, P9, P10, P12)

- 1 of 6 participants used only the drawing response interaction (P5)

Rating

- Solving: 3 of 5 participants rated solving this problem a 6 or 7
 - Note: One participant did not rate this question
 - Average: 5.4
- Drawing response interaction: 5 of 6 participants rated using the drawing response interaction a 6 or 7
 - Note: One participant did not rate this question
 - Average: 6.6

Recommended Features

- Graphs/grids to drag into the drawing response interaction (P6)
- Ability to add labels (P12)

Task 7

Participants were instructed to solve: Kim made a claim about right triangles. If the hypotenuse of one right triangle is congruent to the hypotenuse of another right triangle, then the two triangles are congruent. State whether Kim's claim is correct or incorrect. Provide either an explanation or a counterexample to support your position.

6 of 6 participants attempted the problem

5 of 6 participants used the drawing response interaction and the textbox to answer the question (P1, P5, P6, P9, P10)

- 1 of 6 participants only used the textbox (P12)

Rating

- Solving: 4 of 6 participants rated solving the problem as a 6 or 7
 - Average: 5.8
- Drawing response interaction: 5 of 6 participants rated using the drawing response interaction as a 6 or 7
 - Average: 6

Recommended Features

- Library of shapes to drag into drawing response interaction (P1)
- Tools to use in drawing response interaction (ex: straightedge, compass) (P1)
- Ability to add labels (P1, P12)
- Ability to copy/paste shapes in the drawing response interaction (P10)

Task 8

Participants were instructed to solve: Marcella drew each step of a construction of an angle bisector. Use the steps in the construction to prove that...

5 of 6 participants used the drawing response interaction to re-sketch part 5 of Marcella's construction (P1, P6, P9, P10, P12)

- 1 of 6 participants used both the drawing response interaction and the textbox (P1)
- 1 of 6 participants was not sure how to show his work for the problem (P5)

Rating

- Solving: 1 of 5 participants rated solving the problem a 6 or 7; 4 of 5 participants rated solving the problem a 2 or 3
 - Note: One participant did not rate this question
 - Average: 3.4
- Drawing response interaction: 2 of 5 participants rated using the drawing response

interaction a 6 or 7; 3 of 5 participants rated using the drawing response interaction a 5

- Average: 5.6

Recommended Features

- Tools to use in drawing response interaction (ex: straightedge, compass) (P1)
- Ability to add labels (P6)
- Ability to draw straight lines (P6)

Task 9

Participants were instructed to solve: The figure shows line RS parallel to line UV . The lines are intersected by 2 transversals. All lines are in the same plane. A) Explain why triangle RTS is similar to triangle VTU . B) Given that $m\angle STV=108$ degrees, determine $m\angle SRT+m\angle TUV$.

4 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P1, P5, P6, P10)

- P10: "...I would like a drawing response interaction so I can make up angle measurements to make sure it would all work out."
- P2: "Even if there was an option to draw it out, I would much prefer to write it out."
- P9: "I don't think you would need a drawing response interaction for Part A, because you are just explaining, and the picture is already right there."

4 of 6 participants wanted the ability to label the given shape (P1, P5, P6, P10)

Task 10

Participants were instructed to solve: Let the absolute value of x plus the absolute value of y equal c , where c is a real number. Determine the number of points that would be on the graph of the equation for each given case: Case 1: $c < 0$; Case 2: $c = 0$, Case 3: $c > 0$.

3 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P1, P10, P12)

- P10: "I would like a drawing response interaction just so I could write out my calculations."
- P5: "I would write my answer out, I wouldn't use the drawing response interaction."

At this point in the test, participants were having trouble comprehending the content of the questions

- P9: "If I knew the actual math, it would make more sense."

Recommended Features

- Graphs/grids to drag into the drawing response interaction (P1, P12)
- P12: "If there were an included graph, I would use the drawing response interaction. If not, I wouldn't."

Task 11

Participants were instructed to solve: Do the points on the line $y=3x-2$ have a constant ratio of the y-coordinate to the x-coordinate for any point on the line except the y-intercept?

5 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P1, P5, P6, P9, P10)

- P6: "I would want a drawing response interaction with a graph so I could prove what it is before I explain my answer."
- P9: "I think this one would be really good if you had the drawing box and could add a graph...math is easier using pictures so you can see what you are doing."
- P10: "I would like to be able to graph this, that would help me."

Recommended Features

- Graphs/grids to drag into the drawing response interaction (P1, P6, P9, P10)

Task 12

Participants were instructed to solve: Consider the following claim: If the point $(2+d, y)$ is on the graph of the function $f(x)=x(x-4)$, then the point $(2-d, y)$ is also on the graph. Use algebra to show that the claim is true. What is the relationship between the line $x=2$ and the graph $f(x)$?

5 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P1, P5, P6, P9, P10)

- P6: "I would write down the equations and solve it."
- P12: "I probably wouldn't use a drawing response interaction here. I might use the drawing response interaction if it were more accurate and precise."

Recommended Features

- Graphs/grids to drag into the drawing response interaction (P1, P9)
- Ability to handwrite work/steps (P6, P10)
 - "I definitely need to be able to have something to write out my work here." (S10)

Task 13

Participants were instructed to solve: A dilation centered at point C with a scale factor of k , where $k>0$, can be defined as follows: 1) The image of point C is itself. That is, $C'=C$. 2) For any point P other than C, the point P' is on CP , and $CP'=k*CP$. Use this definition and the diagram shown to prove the following theorem: If $A'B'$ is the image of AB after a dilation centered at point C with a scale factor of k , where $k>0$, then $A'B'=k*AB$.

3 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P6, P9, P10)

- P9: "You don't need a drawing area for this. You just have to explain your answer in the typing box."
- P10: "I'd like to have a thing on the side so I could write out my work and then another one for a final answer so I can draw that out to go along with my explanation."

Recommended Features

- Ability to label/draw on the given diagram (P6)
- Ability to handwrite steps (P10)

Task 14

Participants were instructed to solve: A city plans to implement a composting program. In the composting program, food waste will be collected from the residents and sent to one of these compost collection sites [Table]. A) Based on the given information, determine which composting collection site is cheapest.

4 of 6 participants wanted to use the drawing response interaction to help them solve the problem (P1, P6, P9, P10)

- P1: "I want a (drawing) tool to help me map out of the information."
- P6: "I want a drawing response interaction to help me work out my multiplication and division--a blank space to handwrite my work."
- P9: "You might need an area to draw your model. Maybe an area to redo the [table]."
- P10: "I would definitely need a workspace so I could write it all out. I don't think I could do this one without drawing it."

One participant wanted a larger drawing response interaction

- P1: "I want a bigger or expandable [drawing response interaction]."

Recommended Features

- Ability to handwrite steps (P6, P10)
- Blank table to write in (P6, P9)

- Ability to expand the drawing response interaction (P1)
 - P1: "I want a bigger or expandable [drawing response interaction]."

Physical Interaction with the Computer & iPad

Overall, participants were able to navigate both the computer and the iPad, with a few minor issues

3 of 6 participants who used the iPad for testing indicated they would rather use a computer/mouse than an iPad

- P11: "I'd rather do this on a computer with a mouse (rather than on an iPad)." This participant became frustrated during the test and gave up on multiple tasks.
- P11: "I like computers better (than iPads) because the iPad has a lag."
- P6: "It's difficult for some people to use the mouse to write, but I have experience with it and don't mind."
- P10: "I don't mind using the iPad, but it seems like everything I am at school, there's always something wrong [with the iPads]. I'd be worried about it."

1 of 6 participants struggled with using the mouse

- P3: "Using the mouse is hard. It's wiggly!"

A few participants struggled with some minor iPad issues

- 2 of 6 participants accidentally opened the keyboard and were not sure how to close it.
- 1 of 6 participants accidentally highlighted parts of the question when he was trying to draw. He was unsure how to select the highlighted parts.
- Multiple participants accidentally zoomed when they were trying to erase or draw.

Participants did not specifically comment about line weight or smoothness

FINDINGS & RECOMMENDATIONS

This section discusses positive results and potential issues that became apparent during the study and provides actionable design recommendations to increase the usability of the drawing response interaction.

Overall, participants were comfortable interacting with the drawing response interaction for simple tasks. Some participants had trouble using the drawing response interaction with some of the more complex math problems.

Objective 1: Can participants use the drawing response interaction to help them solve math problems?

Findings
General use of drawing response interaction <ul style="list-style-type: none">12 of 12 participants were able to complete simple tasks (drawing a line and a circle) using the drawing response interaction
Third grade participants experienced issues with the size of the drawing response interaction <ul style="list-style-type: none">5 of 6 third grade participants had difficulty keeping their drawings within the drawing response interaction<ul style="list-style-type: none">P4: "I would write my answer in the drawing box, but my box is full."P1: "I want a big enough drawing tool for all of my information to fit in."Third grade participants ran out of room on 5 different tasks<ul style="list-style-type: none">1 of 6 third grade participants ran out of room on task 4 (P7)2 of 6 third grade participants ran out of room on task 5 (P8, P11)1 of 6 third grade participants ran out of room on task 6 (P4)3 of 6 third grade participants ran out of room on task 7 (P3, P7, P11)1 of 6 third grade participants ran out of room on task 8 (P3)
Eraser Functionality <ul style="list-style-type: none">5 of 12 participants verbally pointed out the "x" eraser tool, but 8 of 12 participants were unable to figure out how to use the eraser toolParticipants expected to be able to erase by dragging the mouse/their fingerP11: "I would want a trashcan if I mess up everything. A square that wipes away like the eraser tool to erase specific things."

Concerns with inaccuracy

- 7 of 12 participants commented on and were concerned by the inaccuracy of their shapes/drawings
 - S10: "[The drawing response interaction] is lagging a bit and I can't get my lines right."

Confusion about Use of Drawing Response Interaction versus Textbox

- 6 of 12 participants indicated being unsure of where to put their answer and/or whether to use both the drawing response interaction and the textbox
 - 1 of 12 participants was unsure of where to put a final answer (P4)
 - 1 of 12 participants wants a separate tool for work and answer (P10)
 - P12: "I'm guessing since the boxes (drawing response interaction and textbox) are next to each other, I can use one or the other. If they were on top of each other, I'd need to use both."
- 3 of 12 participants indicated that they wanted the textbox and palette to be better emphasized
- 1 of 12 participants suggested having just one box in which you could both draw and type (P2)

Rigor of Questions

- The third graders and high schoolers struggled with the rigor of the math questions, which may have impacted their ability to assess and provide recommendations for the drawing response interaction

Recommendations

- **Third grade participants experienced issues with the size of the drawing response interaction**
 - Create the ability to expand the drawing response interaction
 - Adjust the size of the drawing response interaction based on the demands of the question; provide more space for problems requiring more handwritten work
- **Eraser Functionality**
 - Include two types of erasing capability: a) a tool which erases the entire drawing response interaction box (ex: a trashcan icon), b) a draggable eraser tool which enables users to flexibly erase portions of their work
- **Concerns with inaccuracy**
 - Include a library of shapes which can be dragged into the drawing response interaction
 - Allow users to create accurate shapes
 - Eliminate the user worry that being a poor artist will impact their

scores

- **Confusion about Use of Drawing Response Interaction versus Textbox**
 - Include a one- or two-question interactive tutorial at the beginning of the test that enables participants to practice using the drawing response interaction and textbox/palette in a low-stakes manner
 - Include clear directions on how participants are supposed to interact with the drawing response interaction and/or textbox
 - Clearly state whether participants are required to use the drawing response interaction, the textbox, or both
 - Include a clearly designated space for participant answers
- **Rigor of Questions**
 - For future tests, update the included math problems to lower the intrinsic cognitive load of the tasks
 - For some participants, the intrinsic cognitive load of the problems was high enough that they were not able to consider how they would use the drawing response interaction
 - Include less rigorous (yet still rich and complex) problems to give participants a chance to better analyze and assess the drawing response interaction
 - Requiring the participants to show their solution in the drawing response interaction seems to increase the complexity of the task. More than half of the third graders struggled when trying to draw pictures of increased complexity, e.g. the problem where they were expected to represent 5 tables and 6 people sitting around them, and the 10x10 array

Objective 2: What features will participants want to add to the drawing response interaction?

Findings

Below is an overview of the features recommended by the participants, in ranked order from most recommended to least recommended

- **1.) Graphs/grids to drag into the drawing response interaction**
 - Recommended by 7 of 12 participants in 18 different instances
 - Recommended by 2 of 6 third graders
 - Recommended by 5 of 6 high schoolers
- **2.) Library of shapes to drag into drawing response interaction**
 - Recommended by 8 of 12 participants in 20 different instances

- Recommended by 4 of 6 third graders
 - Recommended by 4 of 6 high schoolers
 - Note: 4 participants specifically wanted to be able to add “dots”
- **3.) Ability to label/markup a provided shape/graph** (ex: a shape included in the task prompt)
 - Recommended by 8 of 12 participants in 11 different instances
 - Recommended by 4 of 6 third graders
 - Recommended by 4 of 6 high schoolers
- **4.) Ability to draw straight lines**
 - Recommended by 7 of 12 participants in 12 different instances
 - Recommended by 3 of 6 third graders
 - Recommended by 4 of 6 high schoolers
- **5.) Tool to automatically shade a shape**
 - Recommended by 7 of 12 participants in 7 different instances
 - Recommended by 4 of 6 third graders
 - Recommended by 3 of 6 high schoolers
- **6.) Ability to add labels to the drawing response interaction**
 - Recommended by 5 of 12 participants in 8 different instances
 - Recommended by 2 of 6 third graders
 - Recommended by 3 of 6 high schoolers
- **7.) Ability to handwrite steps/work**
 - Recommended by 5 of 12 participants in 7 different instances
 - Recommended by 2 of 6 third graders
 - Recommended by 3 of 6 high schoolers
- **8.) Tools to use in drawing response interaction (ex: straightedge, compass)**
 - Recommended by 4 of 12 participants in 4 different instances
 - Recommended by 2 of 6 third graders
 - Recommended by 2 of 6 high schoolers
- **9.) Ability to copy/paste**
 - Recommended by 3 of 12 participants in 3 different instances
 - Recommended by 1 of 6 third graders
 - Recommended by 2 of 6 high schoolers
- **10.) Ability to stretch/shrink shapes**
 - Recommended by 2 of 12 participants in 3 different instances
 - Recommended by 2 of 6 third graders
 - Recommended by 0 of 6 high schoolers

Recommendations

Shapes

- Add a library of shapes which allows participants to add a variety of shapes (square, rectangles, triangles, lines, “dots,” etc.) into the drawing response interaction
 - Enable participants to drag shapes into the drawing response interaction
 - Enable participants to stretch/shrink shapes by dragging

Graphs

- Add a library of graph types which allows participants to add a variety of graphs (grids, coordinate planes of different sizes, number lines, etc.) into the drawing response interaction
 - Enable participants to drag graphs into the drawing response interaction
 - For questions requiring graphing, include the coordinate plane/grid in the drawing response interaction

Shading

- Add a shading tool which allows participants to shade a shape or part of a shape
 - participants recommended a spray can icon

Labeling

- Allow participants to label/markup graphs/images included in a problem or allow participants to copy/paste a given graph/image into the drawing response interaction
 - participants expected to be able to draw directly on given images
- Add a labeling tool which allows participants to drag letter and number labels into the drawing response interaction

Ability to Handwrite Steps/Work

- Increase drawing response interaction box size to enable participants to more easily show their work
 - Third graders in particular struggled to keep their work within the box

Tools

- Add a set of tools to help participants more accurately show their work
- participants expected to see a straightedge, protractor, and compass

Copy/Paste

- Allow participants to copy/paste shapes from their drawing response interaction box
- participants want to, for example, draw a line, then copy and paste it so they can ensure they have two lines of the same length.

APPENDIX 1 – MODERATOR’S GUIDE

1. Introductions – introduce team members; Rusty, Kimberly, Susan, Lulu
2. Room Setup – we’ll be recording the session.
3. Purpose – today you’re going to be looking at a new concept to help participants become better prepared for college and career.
4. Feedback – we’ll be going through a series of activities. We want you to think out loud and feel comfortable sharing what you’re thinking. If you are feeling confused, or you have expectations that are not being met, we want to hear about that. Be as honest as possible. If you think something is awful, please say so. Don’t be shy: you won’t hurt anyone’s feelings. Please remember that you may disagree with someone else in the room, and that’s okay. Just keep the conversation honest and respectful.
5. Our goal is to make well-designed products for people like you, so it’s important we understand what you think and what does and doesn’t work for you.
6. Any Questions?

Overview

Demographic Interview: Do you, or have you ever use a computer to complete math assignments?

Scenario: Imagine that you’re about to take a test online. You will be expected to show all of your work within the test on the computer.

Tasks

1. **drawing response interaction (G3 Q 1-3; G9-12 Q 1-5)**
 - Can users successfully use the drawing response interaction to complete the task?
 - Do users identify any other functionality they would like to see added to the drawing response interaction?
- a. [After login] Look over this page and tell me what you think you can do here.

- 1) *How would you expect to be able to use this tool?*
 - 2) *What do you think each of the buttons are for?*
 - 3) *What would you expect to be able to do?*
 - 4) *Is there anything you find confusing?*
- b. Go ahead and do what the question asks.
- 1) *Tell me what you're thinking.*
 - 2) *Is it working like you expect it to?*
 - 3) *Is there anything you find confusing or frustrating?*
 - 4) *Is there anything you'd like the tool to do that it doesn't do now?*

[SEQ Survey: [Insert task] Overall this task was? (rating 1-7)]

2. Multi-step Questions (G3 Q 4-8; G9-12 Q 6-8)

- Can users successfully use the drawing response interaction to complete the task?
 - Do users identify any other functionality they would like to see added to the drawing response interaction?
- c. Here's an actual math problem you might encounter in a test. How would you solve it using the tools provided?

- 1) *How would you use these tools to solve the problem?*
- 2) *What are you thinking?*

[If participants get bogged down with equation editor, redirect them to just use drawing response interaction]

- 3) *How would you expect to be able to use the drawing response interaction?*
- 4) *Is there anything you'd like the tool to do that it doesn't do now?*
- 5) *Is there anything you find confusing or frustrating?*
- 6) Is there anything missing, or would you like something to act/behave differently?
- 7) *What would you add to the drawing response interaction in order to help you solve this problem?*
- 8) *What do you think of the location of the tool?*

[Depending on time, continue through remaining questions, or skip to next section]

[SEQ Survey aligned to content: [Insert task] Overall this task was: (rating 1-7)]

[SEQ Survey aligned to drawing response interaction: [Insert task] Overall this task was: (rating 1-7)]

3. Questions drawing response interaction (G3 Q 9-12; G9-12 Q 9-15)

- o Do users identify any other functionality they would like to see added to the drawing response interaction?
- d. So, these math problems don't have a drawing response interaction. You don't have to actually solve the problem, but can you tell us how the drawing response interaction might help you to answer these questions?
 - 1) *How would the drawing response interaction help you solve the problem or help explain your answer?*
 - 2) *What would you add to the drawing response interaction in order to help you solve this problem?*

[If participants get bogged down with equation editor, redirect them to just focus on features of the drawing response interaction]

- 3) Is there anything missing, or would you like something to act/behave differently?

4. Post-interview

[If not addressed in earlier conversations about drawing response interaction]

- e. Are there any online math tools, apps, etc. that you've used before that help you explain your work, or solve math problems?
 - 1) *If so, what are they? How do they help you?*
 - 2) *What can we do to make it easier for you to show your work/solve the problems?*
 - 3) *[If not already addressed earlier] What would you add to the drawing response interaction in order to help you solve math problems?*

APPENDIX 2--PARTICIPANT VIDEOS

Each participant has a video outlining their interaction with the PARCC drawing response interaction.

All videos can be accessed in the folder [PARCC Usability Sessions July 105- Videos](#), found at <https://pearson.box.com/s/6kt4pf5750zumwmr3dbeuzqizyu2k5ib>.